The geriatric trauma patient: A neglected individual in a mature trauma system

Michael A. Horst, PhD, Madison E. Morgan, BS, Tawnya M. Vernon, BA, Eric H. Bradburn, DO, MS, FACS, Alan D. Cook, MD, MS, FACS, Tamer Shtayyeh, DO, Lauren D'Andrea, BS, *and* **Frederick B. Rogers, MD, MS, MA, FACS***, Lancaster, Pennsylvania*

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BACKGROUND: Those older than 65 years represent the fastest growing demographic in the United States. As such, their care has been emphasized by trauma entities such as the American College of Surgeons Committee on Trauma. Unfortunately, much of that focus has been of their care once they reach the hospital with little attention on the access of geriatric trauma patients to trauma centers (TCs). We sought to determine the rate of geriatric undertriage (UT) to TCs within a mature trauma system and hypothesized that there would be variation and clustering of the geriatric undertriage rate (UTR) within a mature trauma system because of the admission of geriatric trauma patient to nontrauma centers (NTCs).

METHODS: From 2003 to 2015, all geriatric (age >65 years) admissions with an Injury Severity Score of greater than 9 from the Pennsylvania Trauma Systems Foundation (PTSF) registry and those meeting trauma criteria (*International Classification of Diseases, Ninth Revision*: 800–959) from the Pennsylvania Health Care Cost Containment Council (PHC4) database were included. Undertriage rate was defined as patients not admitted to TCs (n = 27) divided by the total number of patients as from the PHC4 database. The PHC4 contains all inpatient admissions within Pennsylvania (PA), while PTSF reports admissions to PA TCs. The zip code of residence was used to aggregate calculations of UTR as well as other aggregate patient and census demographics, and UTR was categorized into lower, middle box, and upper quartiles. ArcGIS Desktop: Version 10.7, ESRI, Redlands, CA and GeoDa: Version 1.14.0, Open source license were used for geospatial mapping of UT with a spatial empirical Bayesian smoothed UTR, and Stata: Version 16.1, Stata Corp., College Station TX was used for statistical analyses.

RESULTS: Pennsylvania Trauma Systems Foundation had 58,336 cases, while PHC4 had 111,626 that met the inclusion criteria, resulting in a median (Q1–Q3) smoothed UTR of 50.5% (38.2–60.1%) across PA zip code tabulation areas. Geospatial mapping reveals significant clusters of UT regions with high UTR in some of the rural regions with limited access to a TC. The lowest quartile UTR regions tended to have higher population density relative to the middle or upper quartile UTR regions. At the patient level, the lowest UTR regions had more racial and ethnic diversity, a higher injury severity, and higher rates of treatment at a TC. Undertriage rate regions that were closer to NTCs had a higher odds of being in the upper UTR quartile; 4.48 (2.52–7.99) for NTC with less than 200 beds and 8.53 (4.70–15.47) for NTC with 200 beds or greater compared with zip code tabulation areas with a TC as the closest hospital.

CONCLUSION: There are significant clusters of geriatric UT within a mature trauma system. Increased emphasis needs to focus prehospital on identifying the severely injured geriatric patient including specific geriatric triage protocols. (*J Trauma Acute Care Surg.* 2020;89: 192–198. Copyright © 2020 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiological, Level III.

KEY WORDS: Geriatric; trauma; undertriage.

Currently, in the United States, the fastest growing demographic is considered to be geriatric (age >65 years). In 2014, 15% of the population was geriatric, and by 2030, it will grow to 21%.[1] Geriatric individuals report increasing prevalence of chronic health conditions.[2] Geriatric trauma has increased as a proportion of trauma patients in trauma registries and is hypothesized to be underestimated because of care provided at lower level or nontrauma centers (NTCs).[3] Because of these factors, care of geriatric patients has been emphasized by trauma entities such as the American College of Surgeons Committee on Trauma. However, much of the focus has been on care once the patients reach the hospital. There has been little attention on the access of geriatric trauma patients (GTPs) to trauma centers (TCs).

Numerous studies have found that undertriage (UT) in trauma patients increases as a factor of age with geriatric patients being of particular risk for undertriage.[4–10] A retrospective analysis looking at 10 years of data in the Maryland Ambulance Information system found that the rate of undertriage in GTPs was significantly higher compared with their younger counterparts. The decrease in trauma transports was found to start at age of 50 years and decrease further at age of 70 years. The authors ultimately concluded that unconscious age bias, in both emergency medical services (EMSs) and TC personnel, may have led to undertriage.[4] There has been prior research conducted showing that GTPs were much more likely to be undertriaged with falls being the most common injury to be undertriaged followed by TBI.[5] Another study found that geriatric patients were less likely to have trauma team activation than younger patients despite a similar percentage of severe injuries. This same study also found that undertriaged geriatric patients had a four times greater mortality rate than younger patients.[6]

Because of the vast amount of research demonstrating that GTPs are more likely to be undertriaged, we sought to determine the geriatric undertriage rate (UTR) and assess differences in GTP triage within a mature trauma system. We hypothesized that there would be variation and clustering of geriatric UTR within a mature trauma system because of the admission of GTP to NTCs.

PATIENTS AND METHODS

We conducted a retrospective analysis for the period of 2003 to 2015 using two databases: the Pennsylvania Trauma Systems Foundation (PTSF) and Pennsylvania Health Care Cost Containment Council (PHC4). Pennsylvania Trauma Systems Foundation is a statewide registry of TC admissions at accredited TC in Pennsylvania (PA). Inclusion criteria for the registry include death secondary to trauma, intensive care unit/step-down

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From the Trauma and Acute Care Surgery (M.A.H., M.E.M., T.M.V., E.H.B., F.B.R.), Penn Medicine Lancaster General Health, Lancaster, Pennsylvania; Department of Surgery, University of Texas Health Science Center at Tyler (A.D.C.), UT Health East Texas, Tyler, Texas; General Surgery Residency Program, Lake Erie College of Osteopathic Medicine (T.S.), Lake Erie, Pennsylvania; and Lewis Katz School of Medicine (L.D.), Temple University, Philadelphia, Pennsylvania.

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Address for reprints: Frederick B. Rogers, MD, MS, MA, FACS, Penn Medicine Lancaster General Health, 555 N Duke St, Lancaster, PA 17604; email: frederick.rogers@pennmedicine.upenn.edu.

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TABLE 1. Summary of ZCTA (n = 1,707) Level Demographics by UTR Group

	Lower Quartile	Middle Box	Upper Quartile	All	*p*
n	427	853	427	1,707	
Median UTR	30.0%	50.5%	65.2%	50.5%	—
Median 13 y trauma (ISS >9) per 1,000 population 65+ y	50.6	51.3	48.8	50.5	0.188
Median 13 y trauma (ISS >15) per 1,000 population 65+ y	29.4	29.5	27.3	28.8	0.030
Median total population density	370.8	198.2	255.2	263.6	<0.001
Median population age 65+ y density	60.7	30.8	43.4	42.9	<0.001

unit admissions, length of stay (LOS) of greater than 48 hours or LOS between 36 and 48 hours with Injury Severity Score (ISS) of 9 or greater, and admitted transfers in/out of the hospital. Since its establishment in 1984 as part of the Emergency Medical Services Act, PTSF has served as the accrediting body for all TCs in the state of PA. Pennsylvania Trauma Systems Foundation accredits adult and pediatric centers alike, in accordance with the American College of Surgeon standards set forth in the Resources for Optimal Care of the Injured Patient.[11] Cases treated at a level I or II adult TC (n = 27) were defined as admissions to a TC for purposes of undertriage calculations because this was seen as the place of definitive care as opposed to level III or IV centers where patients are more likely to be transferred.

The PHC4 is a statewide registry of all inpatient admissions and contains admission to both TCs and NTCs. Since the PHC4 does not include a direct link to PTSF to conclusively identify trauma patients, we selected patients with *International Classification of Diseases, Ninth Revision*, codes ranging from 800 to 959 to identify trauma patients.[12] To calculate an ISS for the PHC4 trauma admissions, we used an algorithm operationalized for Stata Statistical Software by Clark et al.[13] that bases the ISS upon *International Classification of Diseases* codes included in the database. In both databases, we included ISS of greater than 9 to only focus upon trauma cases benefiting from dedicated trauma care and management as well as eliminating minor injuries with marginal trauma relevance. Patients were included in both study data sets if patient age was 65 years or older, ISS was greater than 9, and they were transferred to other hospitals after admission at the initial hospital. Transfers out of the emergency department and patients with home zip code tabulation areas (ZCTAs) outside of PA were excluded.

Patients in both data sets were aggregated to zip code area of residence as a proxy for location of injury and excluded if the zip code was outside of PA.[14–22] For each zip code area, we downloaded and merged census demographics to the TIGER ZCTAs from the US Census Bureau.[23] Patients with PO box zip codes were included in the ZCTAs where the PO box was located. Data from hospitals in PA were extracted from public data files provided by the PA Department of Health and included address for geocoding, licensed bed size, and hospital type.[24] In our mapping, we did include as points of reference TCs outside of PA, which were provided by the American Trauma Society from their 2015 Trauma Information Exchange Program database.

Trauma cases in each ZCTA were aggregated in both the PTSF and the PHC4 databases. Undertriage is defined as any GTP in PA that was not cared for at a TC and was calculated an UTR using the following formula for each ZCTA:

$$\text{UTR} = \frac{(\text{PHC4} - \text{PTSF})}{\text{PHC4}}$$

In addition to the UTR, we calculated a smoothed UTR using the spatial empirical Bayesian method using first-order queen contiguity weighting because of some ZCTAs having small volumes of trauma cases. This smoothing method borrows information from neighboring ZCTAs in cases where there are small numbers of trauma cases and uses a localized prior distribution. A Getis-Ord Gi* procedure was used to identify significant

TABLE 2. Summary of PHC4 Patient Level (n = 111,626) Demographics by UTR Group

	Lower Quartile	Middle Box	Upper Quartile	All	*p*
n	32,214	52,325	27,087	111,626	
Race: White alone	88.7%	90.8%	93.8%	90.9%	<0.001
Race: Black alone	6.0%	3.5%	2.1%	3.9%	
Race: Asian alone	0.7%	0.6%	0.4%	0.6%	
Race: other or unknown	4.6%	5.1%	3.7%	4.6%	
Hispanic	2.3%	0.6%	0.3%	1.0%	<0.001
Female	57.3%	59.1%	60.6%	59.0%	<0.001
Age 65–74 y	26.0%	24.3%	22.6%	24.4%	<0.001
Age 75–84 y	39.7%	39.8%	38.7%	39.5%	
Age 85+ y	34.3%	35.9%	38.7%	36.2%	
Self/uninsured	0.5%	0.3%	0.2%	0.3%	<0.001
Medicare	82.5%	84.2%	84.5%	83.8%	
Medicaid	0.7%	0.4%	0.4%	0.5%	
Commercial	15.8%	14.4%	14.3%	14.8%	
Other/unknown	0.6%	0.6%	0.6%	0.6%	
ISS 10–15	42.0%	42.9%	44.5%	43.1%	<0.001
ISS 16–25	48.3%	48.7%	48.1%	48.5%	
ISS ≥26	9.8%	8.4%	7.4%	8.5%	
AIS head ≥3	50.3%	49.9%	47.3%	49.4%	<0.001
AIS chest ≥3	19.1%	17.0%	16.2%	17.4%	<0.001
AIS abdomen ≥3	3.0%	2.7%	2.3%	2.7%	<0.001
AIS face ≥3	0.1%	0.1%	0.1%	0.1%	0.055
AIS extremities ≥3	26.0%	28.7%	32.0%	28.7%	<0.001
AIS external ≥3	<0.1%	<0.1%	<0.1%	<0.1%	0.828
Transfer in from another hospital	7.0%	12.1%	9.4%	10.0%	<0.001
Transfer to another hospital	3.2%	4.5%	5.1%	4.3%	<0.001
Treated at a TC	84.2%	60.1%	42.6%	62.8%	<0.001
Mortality	7.7%	7.9%	7.1%	7.7%	<0.001
LOS >5 d	42.6%	43.7%	42.8%	43.1%	0.004

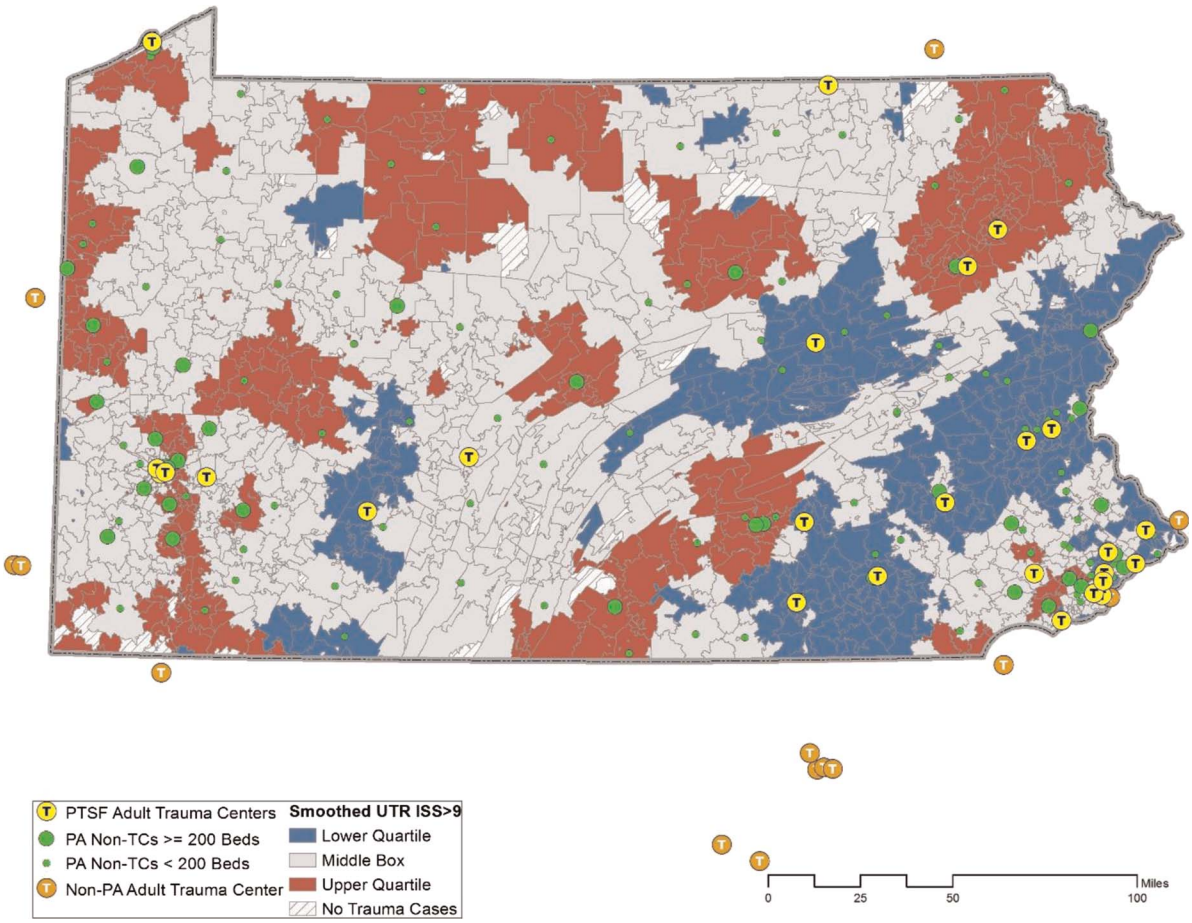

Figure 1. Pennsylvania map of lower quartile, middle box and upper quartile geriatric (age ≥65 years) trauma smoothed UTR for ISS of greater than 9 by ZCTAs with PA accredited and surrounding state TCs and PA NTCs (general hospitals).

clustering of ZCTAs with either high or low geriatric UTR rates.[25] In addition to using ISS of 9 or greater as a cut point, we calculated the smooth UTR using an ISS of 15 or greater to determine if there were any differences in rates of UTR.

We also mapped the smoothed UTR and resulting Getis-Ord Gi* outcomes to provide visualization of the UTR relative to TCs and NTCs and clustering across the state. We divided the state into lower quartile, middle box (middle 50%), and upper quartile regions based upon smoothed UTR to compare various geographic and patient level factors. When patient level factors were assessed, we used the PHC4 database because this was assumed to include all trauma patients regardless of treatment at a TC or NTC. General descriptive statistics were calculated, and inferential tests included χ^2 and Kruskal-Wallis nonparametric tests. Distances from each ZCTA centroid to the nearest hospital based upon the state road network were calculated to determine if the nearest facility was a TC, NTC with less than 200 beds or NTC with 200 beds or greater. We calculated the odds ratios for being in the top quartile of UTR based upon the closest hospital type using a logistic regression model. p Values of <0.05 were considered significant in all analyses. GeoDa: Version 1.14.0, Open source license was used for geospatial analyses, calculation of the spatial empirical Bayesian rates, and the Getis-Ord Gi* model. ArcGIS: Version 10.7, ESRI, Redlands, CA was used for spatial mapping, and Stata: Version 16.1, Stata Corp., College Station TX was used for data preparation and statistical analyses. This study was reviewed and approved by the Penn Medicine/Lancaster General Institutional Review Board.

RESULTS

There were n = 58,336 and n = 111,626 trauma cases (ISS, >9) included in the study from the PTSF and PHC4 databases, respectively, which calculates to a statewide 47.7% UTR of geriatric patients. At the ZCTA level (n = 1,707), the median (Q1–Q3) smoothed UTR was 50.5% (38.2–60.1%) for ISS of 9 or greater. The median (Q1–Q3) smoothed UTR for ISS of 15 or greater was 49.0% (36.8–58.3%). There was not a big difference between UTR rates for ISS of 9 or greater and ISS of 15 or greater. When using ISS of 15 or greater, there were significant areas within the state that the numbers of trauma cases within the rural zip code areas decreased to the point where it became difficult to draw any conclusions about clustering of undertriage. Because of this, the ISS of 9 or greater cut point was used to define UTR. Our definition of the lower quartile, middle box, and upper quartile UTR ZCTA regions was based on these values and lower quartile was defined as less than or equal to 38.2%, middle box was greater than 38.2% to less than 60.1%, and upper quartile was greater than or equal to 60.1%.

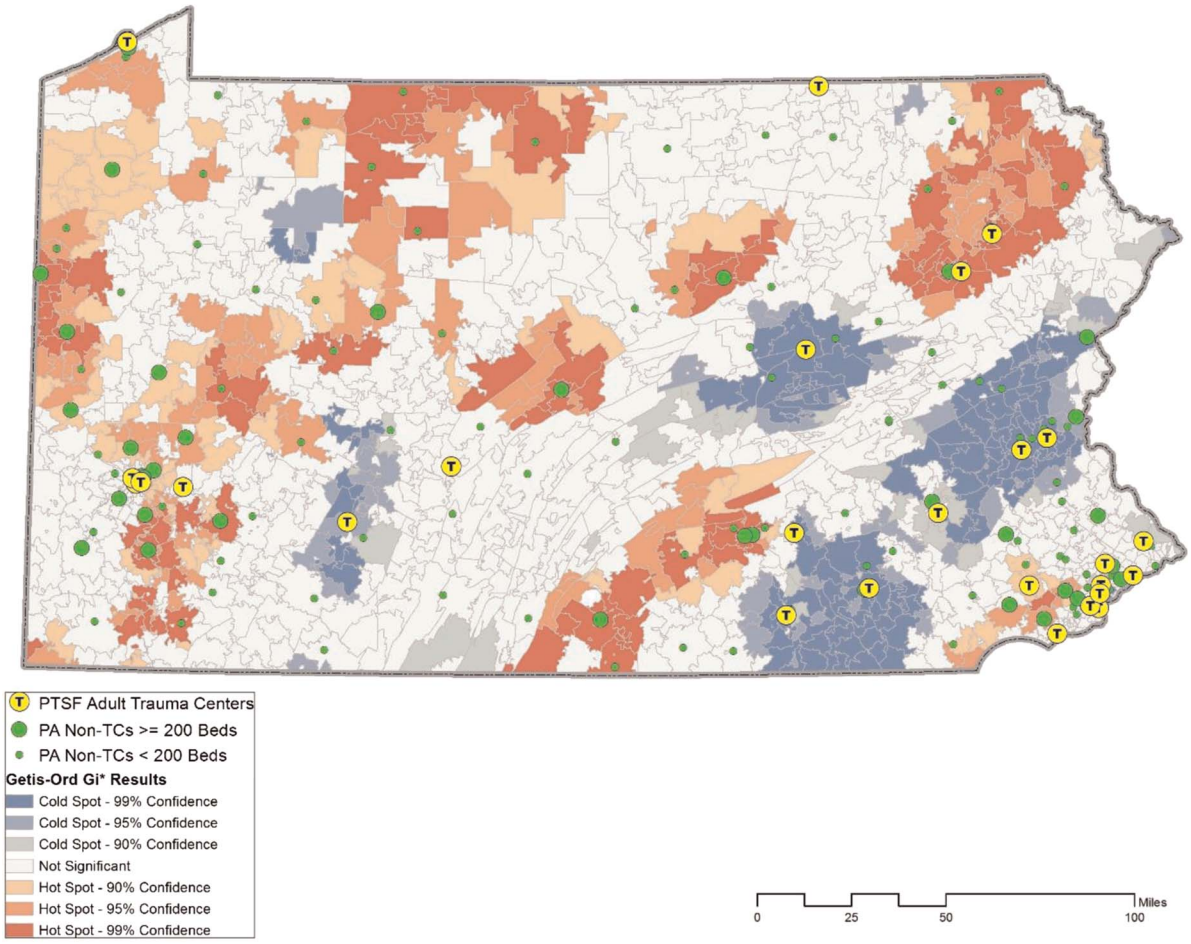

Figure 2. Pennsylvania map of Getis-Ord Gi* clustering analyses of geriatric (age ≥65 years) trauma smoothed UTR for ISS of greater than 9 by ZCTAs.

The lowest UTR regions tended to have higher population density for both the general population and geriatric population relative to the middle or upper quartile UTR regions (Table 1). Median UTR for the lowest quartile was 30.0%; middle box, 50.5%; and upper quartile, 65.2%. At the patient level from the PHC4 database, some of the more notable differences (given the large sample, *p* values have limited utility) include the lowest UTR regions having more racial and ethnic diversity, a higher injury severity, and higher rates of treatment at a TC (Table 2). The most common injuries in this population were to the head and extremities. Around half (49.4%) of patients had a head Abbreviated Injury Scale (AIS) of 3 or greater, while a little more than a quarter (28.7%) of patients had an extremities AIS of 3 or greater (Table 2).

TABLE 3. Odds of Being in the Top Quartile of Smoothed UTR ZCTAs Based Upon Nearest Hospital Type to ZCTA Centroid

Hospital Type	Odds Ratio	95% CI	*p*
TC	Ref.	—	—
NTC <200 beds	4.48	2.52–7.99	<0.001
NTC ≥200 beds	8.53	4.70–15.47	<0.001

Our map (Fig. 1) of the three UTR regions (lower quartile, middle box, and upper quartile) suggested general clustering of these regions, and after applying the Getis-Ord Gi* method, we identified those regions with significant clustering of either high or low rates of UTR (Fig. 2). There were significant clusters of lower UTR in the eastern and one in the western part of the state and significant clusters of higher UTR in the northern, central, and western parts of the state. Our logistic model (Table 3) showed that there was an association of the UTR regions with the types of hospitals (TCs vs. NTCs) nearest (in road miles) to the ZCTA centroid. Zip code tabulation areas with the closest hospital, an NTC with less than 200 beds, had an odds ratio (95% confidence interval [CI]) of 4.48 (2.52–7.99) of being in the upper UTR quartile compared with ZCTAs with a TC as the closest hospital. Zip code tabulation areas with the closest hospital, an NTC with 200 or beds or greater, had an odds ratio (95% CI) of 8.53 (4.70–15.47) of being in the upper UTR quartile compared with ZCTAs with a TC as the closest hospital.

DISCUSSION

The aim of this study was to determine the rate of geriatric undertriage to TCs within a mature trauma system. We

hypothesized that there would be variation and clustering of the geriatric UTR within the PA trauma system. Our results demonstrate that there are, indeed, significant clusters of UTR in within the mature PA trauma system, supporting our hypothesis. Our analysis demonstrated a large amount of clustering and high rates of UTR surrounding NTCs with especially high rates of UTR surrounding NTCs with 200 beds or greater.

Why are the GTPs being undertriaged to NTCs when PA has had mature trauma system implemented for 30 years? There are many potential reasons for this UT to NTC. This may be due to the changing landscape in health care within the state. Smaller hospitals are becoming affiliated with major hospital networks, and, as such, these hospitals are under corporate mandates to keep as many patients within the network-affiliated hospitals as possible (many of which are NTC). It is possible that EMS agencies may elect to bypass certain hospitals because of personal preference and close relationships with some NTCs, leading them to feel more comfortable sending the geriatric patients who are traumas to these NTCs instead of TCs. However, the high rate of undertriage seen in this study more likely represents the inability of EMS providers to recognize the major trauma victim. It would be uncommon for personal preference of EMS personnel to dictate where the patients are transported in PA, as it directly violates the PTSF standards since the PTSF has mandated that all patients meeting CDC criteria[26] be transported to the closest designated TC. Providers in these NTCs may not be in as much of a rush to transport to a TC and think that their injuries are not as severe as they are in actuality and would rather just treat these patients at their community hospitals. Undertriage may also be due to patient preference—they would rather go to their community NTC in their home town then have to get transported somewhere far away for proper care.

The median UTR of all geriatric patients was found to be 50.5%. Previous research conducted by the authors using the same time frame in the Commonwealth of Pennsylvania found that UTR of the pediatric population was 45.8%.[27] Both the UTRs found in this study with regards to the geriatric population and previous rates in the pediatric population are sizable. One would think in a mature trauma system such as PA that the rates of undertriage would be substantially lower. The authors also previously investigated UTR of all adult (age >15 years) trauma patients using the same time frame in PA and determined the UTR to be 32.2%.[28] This adult population did, in fact, include geriatric patients. Taking all three of these studies and age groups, one can infer that the rates of undertriage in vulnerable populations, such as pediatric and geriatric, are much higher than their adult (ages 15–64 years) counterparts. From these studies, it is apparent that both geriatric and pediatric undertriage need to be addressed in an age-specific manner. In addition, since it is suggested both through our current study and multiple other studies[4–10] that GTPs are more likely to be undertriaged, this adds more reason for specific aged-based protocols to be developed to help combat UTR in this particularly vulnerable patient population.

The geospatial maps of PA (Figs. 1 and 2) depicted that there were significant clusters of higher UTR in the northern, western, and central parts of the state, while there were significant clusters of lower UTR in the eastern and one in the western part of the state. The high rates of UTR in the northwest may be due to limited access to TCs. Geriatric patients who had an NTC with less than 200 beds or NTC with 200 beds or greater as their closest hospital were significantly more likely to be undertriaged than those who had a TC as their closest hospital (Adjusted odds ratio [AOR], 4.48, $p < 0.001$; AOR, 8.53, $p < 0.001$, respectively). A study done by Ashley et al.[14] using 5 years of inpatient data from the Georgia Department of Health found that severely injured patients who were treated at a TC had 10% increased probability of survival compared with NTCs. Of note, the existence of a TC does not always eliminate UTR. There are some areas, specifically in the west and northeast part of the state, that have significant clustering of high UTR even with TC in close proximity. These clustering effects are why geospatial representation is imperative to get a more complete picture of the still undetermined influences on UTR.

The benefit of appropriately triaging patients is found within the resources of the trauma service. This often includes, but is not limited to, geriatric services, multiple services involved in patient care along with improved communication, and closer monitoring, as well as physical and occupational therapy. These findings are not implying, by any means, overtriaging a patient population, as that can lead to dwindling the resources within the system.[29,30] In fact, one of the main benefits of appropriate triage is to use the resources within the system meant to help the population. It would be prudent to avoid the prejudice of undertriaging the geriatric population to keep the perpetually fluid pendulum from swinging too far to the other extreme as our aging population continues to expand. Using the resources within a trauma system to allow for and ensure appropriate level of care and appropriate disposition at discharge would help prevent resources being used in a reactionary rather than anticipatory manner.

Given the results, it is clear that, as the TCs mature, the likelihood of undertriage decreases in both the general population and the geriatric population relative to the general population. Unfortunately, even within the mature trauma system, the areas with lower density, further from a TC, are those most at risk for undertriage. The consequence of this is detrimental, because those with the least resources are the ones most likely to be undertriaged and therefore inappropriately managed. If these patients make it to discharge, they are more likely to be discharged with inappropriate disposition highlighting the disparity.

Moving forward, the results of this study call for tighter triage protocols of GTPs. Implementation of EMS geriatric-specific protocol in the field to assess and assure proper triage may be necessary. Geographically, there are areas in the state of PA where access to a TC is very limited. In some places, the TC may be hours away when life-saving care is needed in that moment. Pennsylvania is actively working on improving the trauma system with the creation and implementation of level IV centers to triage and transport. A collective look at PA undertriage through all age groups may be warranted to further help this mature trauma system have optimal coverage in our ever-changing environment.

This study is not without limitations. Because this study was retrospective and only used data from the Pennsylvania Trauma Outcome Study database through the PTSF and PHC4, it may not be applicable to the greater trauma population outside of PA. Also, only the geriatric population was used in this study. Being a trauma registry, Pennsylvania Trauma Outcome Study database, also limits the data to those admitted to an accredited TC, excluding those who were not taken to TCs.

There was limited clinical data in PHC4 since the purpose of PHC4 data is for cost containment, not clinical research. Only geriatric patients meeting trauma criteria were included from PHC4 using billing codes. Billing code errors may have also accidentally influenced study outcomes. This study did not look at the consequences and effects that UTR has on the patient which may limit its clinical applicability. Future research should look at the clinical aspects associated with triage such as morality and functional status at discharge.

CONCLUSIONS

There are significant clusters of UTR in within the mature trauma system of the Commonwealth of Pennsylvania, especially surrounding NTCs. Increased emphasis needs to focus prehospital on identifying the severely injured geriatric patient including specific geriatric triage protocols. A complete picture of undertriage, from pediatric to geriatric, should be done to identify and help prevent these areas of high undertriage in PA.

AUTHORSHIP

M.A.H. contributed in the study design, data collection, data analysis, interpretation of data, and article preparation. M.E.M. contributed in the article preparation, interpretation of data, and literature review. T.M.V. contributed in the study design and interpretation of data. E.H.B. contributed in the study design, interpretation of data, and editorial oversight. A. D.C. contributed in the study design, interpretation of data, and editorial oversight. T.S. contributed in the article preparation. L.D. contributed in the literature review. F.B.R. contributed in the study design, interpretation of data, and editorial oversight.

DISCLOSURE

The authors declare no conflicts of interest.
The opinions and views expressed in this article are solely those of the author(s) and do not represent an endorsement by or position of the Pennsylvania Trauma Systems Foundation.

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